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# SOME FACTORS INFLUENCING THE ROOTING OF VINE CUTTINGS

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A perfect "stand" is rarely obtained in rooting vine cuttings. The difficulty of securing a high percentage of rootings[2] varies greatly with the varieties of the different species and their hybrids. Some of the best phylloxera-resistant stocks are rooted with great difficulty. When the importance of propagating by cuttings and the difficulties of rooting are considered, the value of any treatments or methods of handling which will increase the proportion of cuttings that root or which will improve the quality of the rootings produced is obvious.

The objects of this investigation were to determine the influence on the number of cuttings that rooted and on the quality of the rootings produced of (1) the starch content of the cutting, as indicated by the iodine test, (2) the time of planting, and (3) treatment with oxidizing agents.

## THE STARCH CONTENT OF CUTTINGS AS INDICATED BY THE IODINE TEST

The iodine test as an indication of the stored reserve foods of cuttings has been successfuly applied by some of the leading nurserymen of Europe in selecting stocks for grafting. This test, however, is not used in the selection of cuttings for planting either in the vine

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[2] Rootings, as used in this paper, refers to cuttings which have developed roots and grown for one year in the nursery.

nursery or directly in the field in California. Since the varied climatic conditions of California greatly affect the nutrition of the canes through their influence on the nature of the growth of the vines, the iodine test may be of value in eliminating cuttings which do not possess adequate reserve foods.

In testing the relation of starch content to rooting, as indicated by the iodine test, cuttings of Sultanina were collected from several of the grape-growing sections of the state. The cuttings were made in January and shipped by express to Davis, where they were held in sand in a cool sand pit until the middle of February, when the tests were carried out.

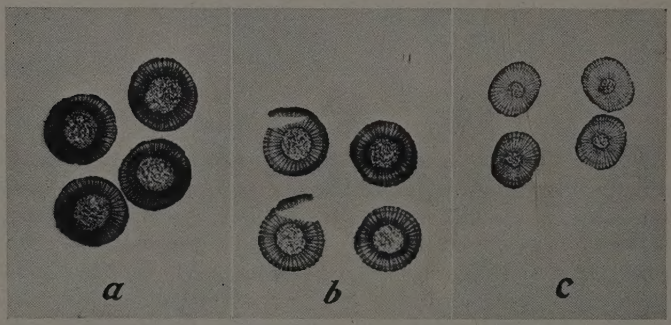


Fig. 1. The different degrees of intensity of staining with iodine corresponding to the starch content of the cuttings in the several groups. *a*, Group 1. *b*, Group 2. *c*, Group 3.

In making the tests, freshly cut ends of two hundred cuttings of each lot were immersed for one minute in a 0.2 per cent solution of iodine in potassium iodide. By means of this uniform exposure to the iodine solution, it was possible as a result of the different degrees of intensity of staining obtained to divide the cuttings into the following groups:

Group 1: Cuttings which showed deep staining throughout the wood and very dark staining in the medullary rays (fig. 1, A).

Group 2: Cuttings which showed only faint staining in the wood near the cortex, slight staining of the wood adjacent to the pith, and deep staining in the medullary rays (fig. 1, B).

Group 3: Cuttings which showed no staining in the wood near the cortex, faint staining of the wood adjacent to the pith, and well defined staining in the medullary rays (fig. 1, C).

Although it was impossible to make a very rigid classification of cuttings by this method of selection, the grouping as indicated above appears to be serviceable for practical purposes. The results, at least, seem to indicate that the slight overlapping of the groups which of necessity occurred, was not sufficient to greatly influence the results. The percentage of rootings obtained under the different groups is given in table 1.

TABLE 1

THE INFLUENCE OF THE STARCH CONTENT ON THE PERCENTAGE AND THE VIGOR OF THE ROOTINGS PRODUCED

| | Cuttings with high starch content (Group 1) | Cuttings with medium starch content (Group 2) | Cuttings with low starch content (Group 3) |
|---|---|---|---|
| Per cent rooted | 62.5 | 35.3 | 16.9 |
| Per cent of vigorous rootings produced | 30.0 | 9.3 | 1.8 |

The figures of table 1, which are percentages of the number of cuttings planted, indicate that there is a more or less direct relationship between the starch content of the cuttings and the number of rootings produced. The data further indicate that the vigor of the rootings produced is also closely correlated with the starch content.

TABLE 2

THE RELATION OF REDUCING SUBSTANCES AND STARCH CONTENT TO THE NUMBER AND VIGOR OF THE ROOTINGS PRODUCED UNDER THE SEVERAL GROUPS

| | Cuttings with high starch content (Group 1) | Cuttings with medium starch content (Group 2) | Cuttings with low starch content (Group 3) |
|---|---|---|---|
| Per cent of reducing substances | 2.27 | 2.30 | 2.12 |
| Per cent of starch | 5.68 | 3.72 | 2.56 |
| Per cent of cuttings rooted | 85 | 42.5 | 23.5 |
| Per cent of vigorous rootings | 53.1 | 17.0 | 5.1 |

As a further check on the reliability of the iodine test, analyses were made of a considerable number of cuttings of the different groups. These analyses, together with the percentage and vigor of the rootings produced, are given in table 2.

The figures of table 2 indicate that the iodine test is relatively accurate and that it may, at least for practical purposes, serve as a means of determining the storage of reserve foods of cuttings. The

figures also emphasize the relation of the starch content to the viability of the cuttings. There seems to be no relation between the starch content and the amount of reducing substances, since the latter substances are present in about the same amount in each of the groups of cuttings.

It is also of interest to note that the vigor of the rootings produced was closely correlated with their composition. Although the rootings of the cuttings lower in starch had a greater space in the nursery row, owing to a greater mortality, this advantage did not enable them to equal the vigor of the rootings of the cuttings of higher starch content. This difference in mortality and its influence on spacing for groups 2 and 3 is shown in figure 2.


Fig. 2. The relation of starch content to the mortality of cuttings in the nursery and the effect of the death of cuttings on the spacing of the remaining rootings. *a*, Group 2. *b*, Group 3.

## TIME OF PLANTING

During the seasons of 1924 and 1925, lots of two hundred cuttings each were planted at varying intervals, from December of the previous year to May. These plantings were made to determine, if possible, the influence of the time of planting on the number and vigor of rootings produced. The results obtained during the two seasons are listed in table 3.

The figures of table 3 show a considerable advantage in favor of the earlier plantings with regard to both the total number of rootings produced and the quality of the rootings. All cuttings planted after the middle of March were very unsatisfactory. The falling off in

TABLE 3

THE EFFECT OF TIME OF PLANTING ON THE NUMBER AND VIGOR OF ROOTINGS
(The percentage of rootings produced by the earliest planting is taken as 100)

| Variety | Date of planting | Per cent of cuttings that rooted | Per cent of vigorous rootings produced |
|---|---|---|---|
| Alicante Bouschet | Dec. 20, 1923 | 100 | 67 |
| | Jan. 16, 1924 | 90 | 58 |
| | Feb. 18, 1924 | 89 | 49 |
| | Mar. 20, 1924 | 53 | 40 |
| | Apr. 15, 1924 | 38 | 31 |
| | May 15, 1924 | 46 | 12 |
| Sultanina | Dec. 31, 1924 | 100 | 77 |
| | Feb. 2, 1925 | 82 | 59 |
| | May 3, 1925 | 24 | 6 |
| Muscat | Dec. 31, 1924 | 100 | 65 |
| | Feb. 2, 1925 | 67 | 30 |
| | May 3, 1925 | 35 | 8 |

both the quality and quantity of rootings produced, however, is more or less uniform from the earliest to the latest plantings.

The figures of table 4 and the illustrations of figure 3 indicate why earlier planting gave the better quality and probably also the greater percentage of rootings. These data show that the cuttings of the earlier planting started root development much in advance of those of the late plantings. This not only tended to extend the growing season but also gave the roots a start before the buds pushed.

TABLE 4

THE CONDITION OF ROOT AND TOP DEVELOPMENT OF ALICANTE BOUSCHET CUTTINGS OF THE VARIOUS PLANTINGS ON APRIL 15, 1924

| Date of planting | Per cent of cuttings showing root development | Average number of roots per cutting | Average length of the individual roots *cm.* | Per cent of cuttings showing top development |
|---|---|---|---|---|
| Dec. 20, 1923 | 60 | 4.5 | 8.9 | 5 |
| Jan. 16, 1924 | 50 | 3.4 | 8.3 | 7 |
| Feb. 18, 1924 | 40 | 3.0 | .4 | 3 |
| Mar. 20, 1924 | 20 | 2.5 | .1 | 0 |
| Apr. 15, 1924 | 0 | 0 | 0 | 0 |
| May 15, 1924 | 0 | 0 | 0 | 0 |

## TREATMENT WITH CHEMICAL COMPOUNDS THAT EXERCISE STIMULATORY EFFECTS

In the tests of chemical treatments, an attempt was made to improve the rooting of grape cuttings by utilizing the findings of Curtis(2) and others, who have shown that various chemicals, especi-

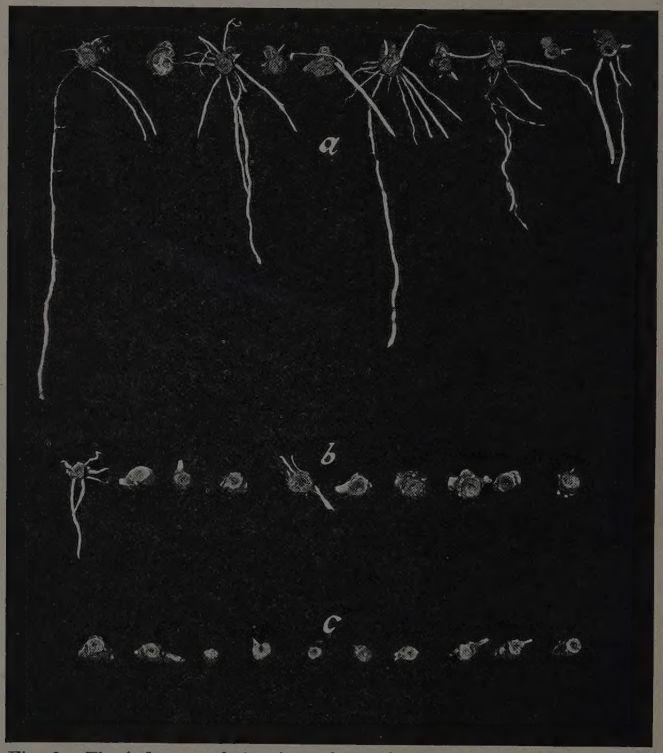


Fig. 3. The influence of the time of planting on the stage of root development on April 15. *a*, Planted December 20. *b*, Planted February 18. *c*, Planted March 20.

ally oxidizing reagents, stimulate root growth. In these tests, cuttings were subjected to continuous contact or to preliminary treatments of short duration in solutions of the various compounds in distilled water. In the continuous treatments, the cuttings were rooted in flasks containing the solution. In the limited treatments, the cuttings

were left in the solution in most cases for forty hours. In all of the treatments about one inch of the base of the cuttings was immersed in the solution.

In a few of the earlier of these tests, twenty cuttings were used in each lot; however, in the majority of the trials, fifty cuttings were used. Glass jars placed on the laboratory bench served as containers for the cuttings. For callusing in sand, the cuttings were reversed in a sand pit with a southern exposure which was covered with glass. The temperature was not controlled. However, where comparisons are made between lots treated with different compounds, the cuttings were all treated as nearly alike as possible with respect to exposure to light and temperature.

In the comparisons, the average percentage of rootings, the vigor of the rootings, the average total length of top and root growth (for the newly rooted cutting), and the diameter of the roots for the one-year-old rootings are used. The length of individual roots and shoots varied too greatly for comparisons of these to be consistent.

Data have been collected on the effect of the duration of treatment and of the concentration of solution of the various compounds together with their influence on the rate of root and callus formation and on the number and vigor of the rootings produced.

*Concentration of Solution.*—In tests of the effect of concentration of solution twenty cuttings were treated for 24 hours in each of the several concentrations of solution of the several different compounds. After treatment, the cuttings were callused in sand for 14 days. The results of these tests are given in table 5.

The figures of table 5 indicate that cuttings, in the stage of dormancy, of the Alicante Bouschet (a variety of *Vitis vinifera*) cuttings used, are tolerant of a considerable range in the concentration of the reagents without loss of the stimulating effect. This tolerance is a factor of much importance, if this form of root stimulation is to be applied in practice where an accurate control of the concentration of the reagents is difficult.

The concentrations giving the greatest stimulations were .001 to .0001 mol. solutions of $MnSO_4$, $Mn_2(SO_4)_3$, $K_3Fe(CN)_6$, and iodine; .01 to .001 mol. solutions of $MnO_2$, $FeCl_3$, and $Na_2O_2$, and .1 to .05 mol. solutions of $H_2O_2$ and $KMnO_4$. The greatest concentrations of solution in these tests, except for the $H_2O_2$ and $FeCl_3$, were approaching the maximum concentration that could be used without injury, since the root growth under these was little or no better than that of the check.

TABLE 5

THE INFLUENCE OF CONCENTRATION OF SOLUTION OF THE SEVERAL COMPOUNDS ON THE FORMATION OF ROOTS ON ALICANTE BOUSCHET CUTTINGS

| Reagent | Mol. concentration | Per cent of cuttings rooted | Average total root length per cutting |
|---|---|---|---|
| Water (check) | Distilled | 30 | 4.2 |
| $KMnO_4$ | .05 | 70 | 9.7 |
| | .1 | 100 | 32.1 |
| | .2 | 40 | 6.5 |
| $MnO_2$ | .001 | 90 | 52.2 |
| | .01 | 95 | 59.2 |
| | .1 | 70 | 35.7 |
| | .2 | 40 | 16.0 |
| $Na_2O_2$ | .001 | 95 | 72.6 |
| | .01 | 70 | 47.7 |
| | .05 | 35 | 5.9 |
| | .1 | 30 | 2.4 |
| $FeCl_3$ | .0001 | 40 | 11.6 |
| | .001 | 65 | 68.8 |
| | .01 | 75 | 47.6 |
| $MnSO_4$ | .0001 | 85 | 81.3 |
| | .001 | 100 | 112.3 |
| | .01 | 75 | 47.6 |
| $Mn_2(SO_4)_3$ | .0001 | 65 | 21.1 |
| | .001 | 65 | 12.5 |
| | .01 | 35 | 8.7 |
| $H_2O_2$ | .001 | 55 | 32.6 |
| | .01 | 40 | 19.5 |
| | .1 | 75 | 45.0 |
| | .5 | 90 | 58.0 |
| $K_3Fe(CN)_6$ | .0001 | 90 | 16.0 |
| | .001 | 95 | 28.8 |
| | .01 | 60 | 6.8 |
| $K_4Fe(CN)_6+3H_2O$ | .0001 | 35 | 6.7 |
| | .001 | 25 | 4.2 |
| I | .0001 | 80 | 87.8 |
| | .001 | 65 | 51.0 |
| | .01 | 35 | 4.6 |
| KI | .0001 | 35 | 8.0 |
| | .001 | 30 | 5.6 |
| | .01 | 20 | 2.5 |

The data of table 5 show also a relatively close correlation between the number of cuttings that rooted and the average total length of roots to a cutting. The data in a later part of this paper show that this correlation holds throughout the entire season where the treated cuttings are planted in the nursery.

The two reducing substances, namely $K_4Fe(CN)_6 \cdot 3H_2O$ and KI, listed in table 5 were included to test the belief of some workers that the stimulation of root growth is possibly due to the ions present in a compound and not to its properties as regards oxidation or reduction.

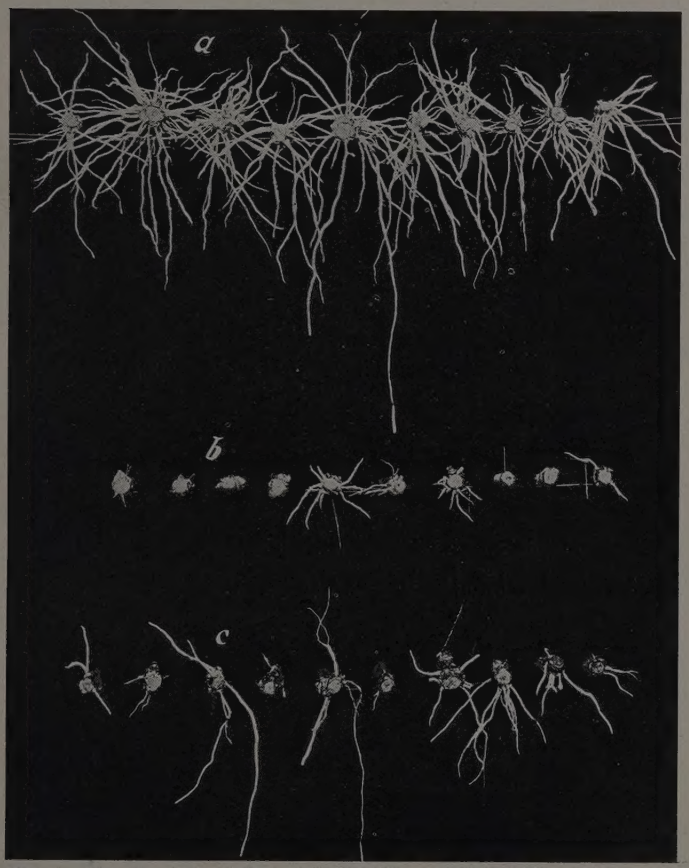


Fig. 4. The stimulating effect of $K_3Fe(CN)_6$ and $K_4Fe(CN)_6 \cdot 3H_2O$ on the development of roots. *a*, $K_3Fe(CN)_6$. *b*, Water. *c* $K_4Fe(CN)_6 \cdot 3H_2O$.

Figure 4 shows the respective stimulating effects on root development of $K_3Fe(CN)_6$ and $K_4Fe(CN)_6 \cdot 3H_2O$. The stimulation seems to be associated with the oxidizing properties of the $K_3Fe(CN)_6$, since the same ions are present in these two reagents. Similar results were obtained with the iodine and potassium iodide.

The $K_4Fe(CN)_6 \cdot 3H_2O$ did produce a slight increase in root development. This small stimulation, however, which is within the limits of experimental error, might also be the result of chemical injury.

*Duration of Treatment.*—Twenty cuttings were placed in an individual jar for each of the periods of treatment for every concentration

TABLE 6

THE INFLUENCE OF DURATION OF TREATMENT ON THE DEVELOPMENT OF ROOTS

| Variety | Reagent | Molar concentration | Duration of treatment in hours | Per cent of cuttings with roots | Average total length of roots per cutting in centimeters after callusing |
|---|---|---|---|---|---|
| Black Monukka..... | Water | Check | 24 | 20 | 2.7 |
| (Variety of *Vitis vinifera*) | Water | Check | 60 | 20 | 2.5 |
| | Water | Check | 120 | 10 | 1.0 |
| | $KMnO_4$ | .1 | 24 | 80 | 109.0 |
| | $KMnO_4$ | .1 | 60 | 100 | 143.0 |
| | $KMnO_4$ | .1 | 120 | 60 | 40.0 |
| | $KMnO_4$ | .25 | 24 | 60 | 45.0 |
| | $KMnO_4$ | .25 | 60 | 55 | 36.0 |
| | $KMnO_4$ | .25 | 120 | 15 | 31.0 |
| | $KMnO_4$ | 1.0 | 24 | 30 | 5.0 |
| | $KMnO_4$ | 1.0 | 60 | 15 | 1.0 |
| | $KMnO_4$ | 1.0 | 120 | 0 | 0.0 |
| | Water | Check | 24 | 40 | 4.3 |
| | Water | Check | 48 | 40 | 4.9 |
| | $MnSO_4$ | .001 | 24 | 60 | 51.0 |
| | $MnSO_4$ | .001 | 48 | 100 | 78.0 |
| | $MnSO_4$ | .01 | 24 | 70 | 57.0 |
| | $MnSO_4$ | .01 | 48 | 60 | 45.0 |
| | $FeCl_3$ | .001 | 24 | 68 | 58.0 |
| | $FeCl_3$ | .001 | 48 | 80 | 74.0 |
| | $FeCl_3$ | .01 | 24 | 85 | 74.0 |
| | $FeCl_3$ | .01 | 48 | 70 | 67.0 |

of solution. At the time the cuttings of the shortest period of treatment were removed to the sand, the solutions on the others were changed. The same changes were again made when the cuttings for the next period of treatment were removed. All cuttings were callused in sand for 14 days after their removal from the solutions. The results for different periods of treatment with three different reagents are given in table 6.

The data of table 6 indicate that the duration of treatment as well as the concentration of the solution of the reagent may influence the

stimulation of root formation. That is, with a low concentration of solution, a longer period of treatment may give results comparable to a shorter treatment with a higher concentration of solution. This is well illustrated by the treatments with $MnSO_4$ and $FeCl_3$. For the 24-hour treatment, the .01 mol. solutions for these reagents gave the best results, while for the 48-hour treatment, the .001 mol. solution

TABLE 7

THE INFLUENCE OF OXIDIZING REAGENTS ON THE RATE OF ROOT AND CALLUS FORMATION ON CUTTINGS

| Variety | Treatment with conc. of reagent | Treatment duration | Callusing nature and time | Per cent with roots | Average total length of roots, *cm.* | Per cent of cuttings without roots | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Good callus | Poor callus | Without callus |
| *Champini* | Water (check) | 40 hours | 16 days reversed in sand pit. | 0 | 0.0 | 0 | 40 | 60 |
| | .001 m. $MnSO_4$ | 40 hours | | 100 | 67.0 | 0 | 0 | 0 |
| | .001 m. $K_3Fe(CN)_6$ | 40 hours | | 70 | 87.0 | 20 | 10 | 0 |
| | .01 m. $Na_2O_2$ | 40 hours | | 90 | 52.0 | 10 | 0 | 0 |
| *Champini* | Water (check) | Continuous | 20 days in the solutions in hot room. | 33 | 12.0 | 15 | 25 | 25 |
| | .0001 m. $MnSO_4$ | Continuous | | 95 | 22.0 | 0 | 0 | 5 |
| | .0001 m. $K_3Fe(CN)_6$ | Continuous | | 71 | 49.0 | 15 | 5 | 9 |
| | .001 m. $Na_2O_2$ | Continuous | | 71 | 23.0 | 24 | 5 | 0 |
| | .001 m. $KMnO_4$ | Continuous | | 38 | 25.0 | 30 | 20 | 12 |
| *Labrusca* (Pierce) | Water (check) | 40 hours | 18 days reversed in sand. | 0 | 0.0 | 10 | 50 | 40 |
| | .001 m. $K_3Fe(CN)_6$ | 40 hours | | 90 | 35.0 | 10 | 0 | 0 |
| *Labrusca* (Pierce) | Water (check) | Continuous | 20 days in the solutions in hot room. | 25 | 5.0 | 25 | 30 | 20 |
| | .0001 m. $MnSO_4$ | Continuous | | 100 | 58.0 | 0 | 0 | 0 |
| | .0001 m. $K_3Fe(CN)_6$ | Continuous | | 66 | 12.0 | 15 | 3 | 10 |
| | .001 m. $Na_2O_2$ | Continuous | | 66 | 17.0 | 25 | 8 | 0 |
| *Vinifera* x *Berland.* (41B) | Water (check) | 40 hours | 12 days reversed in sand. | 0 | 0.0 | 20 | 10 | 66 |
| | .001 m. $MnSO_4$ | 40 hours | | 20 | 23.0 | 34 | 25 | 21 |
| | .001 m. $K_3Fe(CN)_6$ | 40 hours | | 4 | 20.0 | 34 | 35 | 33 |
| | .01 m. $Na_2O_2$ | 40 hours | | 4 | 25.0 | 54 | 30 | 14 |
| | .01 m. $KMnO_4$ | 40 hours | | 12 | 7.0 | 30 | 40 | 18 |

gave the greater stimulation. Similar relations of time of treatment to concentration are indicated by the tests with $KMnO_4$.

*Rate of Callus and Root Formation.*—In these tests only varieties were used which are difficult to root. Fifty cuttings were used in each lot. The concentration of solution and duration of treatment employed were those which gave the best results in preliminary tests. The influence of the several reagents used on the rate of callus and root formation is shown in table 7.

As shown by the figures of table 7, all of the reagents employed induced a marked stimulation in callus and root formation. In each series for each variety, the callus and root formation of the treated lots was far ahead of the checks treated with water.


Fig. 5. The stimulating effect of $MnSO_4$ and $K_3Fe(CN)_6$ on the formation of roots on Pierce cuttings. *a*, $MnSO_4$. *b*, Water. *c*, $K_3Fe(CN)_6$.

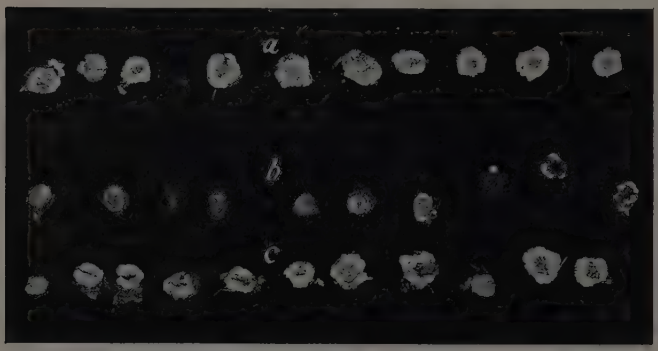


Fig. 6. The stimulating effect of $MnSO_4$ and $K_3Fe(CN)_6$ on the formation of callus on 41B cuttings. *a*, $MnSO_4$. *b*, Water. *c*, $K_3Fe(CN)_6$.

These data indicate also that in all the series in which it was employed, $MnSO_4$ gave the greatest stimulation as shown by the percentage of cuttings with roots. The $K_3Fe(CN)_6$ gave the next best stimulation of root formation, if both the percentage of cuttings with roots and the average total length of roots per cutting are considered.

The $Na_2O_2$ was only slighly less stimulating than the $K_3Fe(CN)_6$, while the $KMnO_4$, which has possibly received the most attention in the past as a stimulant of root growth, gave the poorest results.

The stimulating influence of $MnSO_4$ and $K_3Fe(CN)_6$ is further indicated by figure 5. These cuttings of Pierce were treated continuously for 20 days and were then held in sand 6 days before photographing. The effect of these same reagents on the formation of callus on 41B cuttings is illustrated in figure 6. Those shown here

TABLE 8

THE INFLUENCE OF CERTAIN OXIDIZING REAGENTS ON THE PERCENTAGE OF CUTTINGS THAT ROOT

| Reagent | Duration of the treatment, in hours | Variety and the percentage that rooted | | |
|---|---|---|---|---|
| | | 41B | Champini | Pierce |
| Water (check) | 24 | 40 | 50 | 40 |
| $KMnO_4$ .1 mol | 24 | 100 | 60 | ..... |
| $KMnO_4$ .05 mol | 48 | 90 | ..... | 65 |
| $MnSO_4$ .001 mol | 48 | 100 | 80 | 100 |
| $FeCl_3$ .01 mol | 24 | 80 | 60 | ..... |
| $K_3Fe(CN)_6$ .001 mol | 24 | 100 | 87 | 80 |
| Sand (planted direct from sand pit) | ..... | 25 | 30 | 20 |

are ten average cuttings of the lots listed in table 7 for these treatments of this variety. The photograph, however, was taken after the cuttings had been in the sand for only 8 days, which was before any roots had formed. It is, of course, a well known fact that a heavy formation of callus does not necessarily indicate that root formation will follow, or that the absence of callus precludes the formation of roots. Rooting may be independent of callus formation. However, as is shown by figures 7 and 10, the formation of callus on these cuttings was an indication of their respective rates of development.

*Number and Vigor of the Rootings Produced.*—Fifty cuttings of each variety were used for each of the reagents. The cuttings were treated 40 hours in the solutions and then callused in sand before planting. In the nursery the cuttings were planted six inches apart in rows spaced six feet. The influence of the treatment on the number and vigor of the rootings for the varieties tested during 1924 is given in tables 8 and 9.

The data of table 8 show a considerable increase in the percentage of cuttings that rooted for each of the varieties as a result of the treatments. The greatest increases were obtained in 41B and the least in Champini. There was little difference in the stimulating effect of the several reagents.

Of equally as great significance as the increase in the percentage of rootings produced is the increase in the number of first class or vigorous rootings. Some measurements made at the end of the first

TABLE 9

THE INFLUENCE OF CERTAIN OXIDIZING REAGENTS ON THE VIGOR OF THE ROOTINGS

| Variety | Treatment | Per cent of rootings that were vigorous | Relative circumference increase in centimeters | Total length of top growth in centimeters | Average diameter of individual roots in mm. |
|---|---|---|---|---|---|
| Champini | Check (in water)..... | 28 | .4 | 166 | ..... |
| | $MnSO_4$ .001 mol..... | 88 | 2.4 | 439 | ..... |
| | $FeCl_3$ .001 mol..... | 83 | 2.3 | 490 | ..... |
| | $KMnO_4$ .05 mol..... | 83 | 1.5 | 416 | ..... |
| | Check (planted directly from sand pit)..... | 0 | .7 | 122 | ..... |
| 41B..... | Check (in water)..... | 20 | 1.3 | ..... | 1.9 |
| | $MnSO_4$ .001 mol..... | 80 | 2.5 | ..... | 3.6 |
| | $FeCl_3$ .01 mol..... | 75 | 2.7 | ..... | 3.3 |
| | $KMnO_4$ .05 mol..... | 75 | 2.7 | ..... | 2.9 |
| | Check (planted directly from sand pit)..... | 5 | .3 | ..... | 1.4 |

season's growth in the nursery on the difference in the vigor of the rootings produced by the treated lots as compared to the checks are given in table 9.

The data of tables 8 and 9 indicate that the increase in vigor was more pronounced than the increase in the percentage of rootings. That is, 41B gave a rooting percentage of 40 in water and 100 in .001 mol. $MnSO_4$ (table 8), while the percentage of vigorous rootings was 20 and 80, respectively (table 9). Similarly, the Champini in water had a rooting percentage of 50 and in $MnSO_4$ 80, while the percentage of vigorous rootings produced under these treatments was 28 and 88, respectively. The same is true for the other treatments.

The influence of the several oxidizing agents employed, on the number and vigor of the rootings produced during 1925, was similar to that of 1924. Additional data, however, were collected and

the probable error of some of the measurements determined; hence, the results may serve as a better basis of comparisons than those of tables 8 and 9. The influence of these treatments on the number and vigor of the rootings produced is given in table 10 and the influence on root develepment is illustrated further in figures 7 and 10.

TABLE 10

THE INFLUENCE OF CERTAIN OXIDIZING REAGENTS ON THE NUMBER AND VIGOR OF ROOTINGS PRODUCED

| Variety | Treatment | Mol. conc. of reagents | Per cent of cuttings rooted | Per cent of rootings that were vigorous | Number of good rootings from 100 cuttings | Circum. increase in centimeters | Average total length of top growth *cm.* | Average number of roots to a plant | Average diameter of individual roots *mm.* |
|---|---|---|---|---|---|---|---|---|---|
| Champini | Water | | 70 | 50 | 35 | .53±.14 | 140±24 | 5.8 | 2.8±.23 |
| | $MnSO_4$ | .001 | 100 | 100 | 100 | 1.11±.16 | 244±13 | 7.3 | 3.8±.20 |
| | $K_3Fe(CN)_6$ | .001 | 100 | 90 | 90 | 1.37±.21 | 312±24 | 8.8 | 4.1±.18 |
| | $Na_2O_2$ | .01 | 100 | 100 | 100 | .97±.17 | 313±17 | 7.8 | 3.8±.20 |
| | $KMnO_4$ | .01 | 85 | 90 | 76 | .85±.13 | 230±15 | 7.1 | 3.5±.16 |
| Pierce | Water | | 52 | 40 | 21 | .39±.07 | 71±8.4 | 6.4 | 2.3±.09 |
| | $MnSO_4$ | .001 | 100 | 90 | 90 | .86±.11 | 204±16 | 6.8 | 3.1±.17 |
| | $K_3Fe(CN)_6$ | .001 | 100 | 87 | 87 | .72±.10 | 185±10.2 | 7.7 | 2.8±.18 |
| | $Na_2O_2$ | .01 | 75 | 66 | 50 | .65±.08 | 155±13 | 5.7 | 3.6±.22 |
| | $KMnO_4$ | .01 | 65 | 50 | 33 | .54±.08 | 142±8 | 6.2 | 2.9±.15 |
| 41B | Water | | 30 | 10 | 3 | .67±.07 | 47±10.2 | 2.7 | 2.0±.19 |
| | $MnSO_4$ | .001 | 95 | 85 | 80 | 1.09±.10 | 218±33 | 5.6 | 3.3±.21 |
| | $K_3Fe(CN)_6$ | .001 | 90 | 89 | 80 | .97±.11 | 192±15 | 6.4 | 3.3±.19 |
| | $Na_2O_2$ | .01 | 75 | 70 | 52 | .93±.13 | 196±17 | 5.7 | 3.1±.13 |
| | $KMnO_4$ | .01 | 65 | 72 | 47 | .86±.07 | 144±16 | 4.8 | 2.8±.17 |

The data of table 10 show very marked increases in both the number and the vigor of the rooting produced in the treated lots as compared to the checks. Here again there was little difference in the results obtained for the different compounds, except that the results with $KMnO_4$ were somewhat less marked than those for the other three reagents.

The matter of greatest importance in the possible application of these treatments to practice, however, is the increase in the number of vigorous rootings produced by each 100 cuttings planted. It has been shown by Bioletti(1) that the strongest 25 per cent of 630 Muscat rootings produced 50 per cent more crop at the first vintage than the weakest 25 per cent of these rootings. He believes that the advantage of the strongest rootings was in reaching nearly full bearing the third season instead of the fourth as with the weaker rootings.

The increases over the check in Champini in the number of vigorous rootings were 186, 171, 186, and 117 per cent, respectively, for the $MnSO_4$, $K_3Fe(CN)_6$, and $Na_2O_2$, and $KMnO_4$. In 41B and Pierce, the increases for the treatments used were even greater.

The increases in circumference of the cuttings treated with $MnSO_4$, $K_3Fe(CN)_6$, $Na_2O_2$, and $KMnO_4$ exceeded those of the check in Champini by 109, 158, 83, and 68 per cent, and in Pierce by 112, 82, 67, and 38 per cent, respectively. Similar increases were realized with 41B.

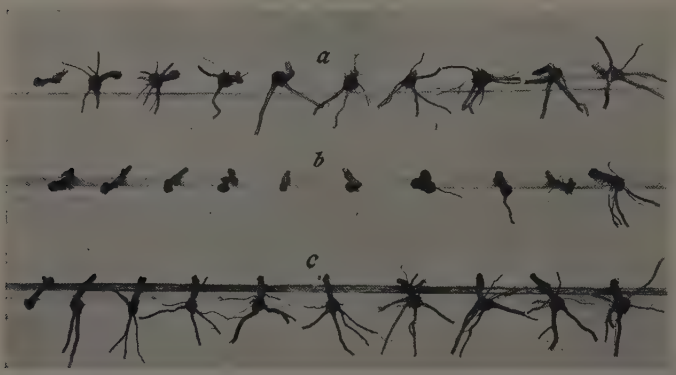


Fig. 7. The influence of $MnSo_4$ and $K_3Fe(CN)_6$ on the number and vigor of the roots produced by Champini cuttings at the end of the growing season. *a*, $K_3Fe(CN)_6$. *b*, Water. *c*, $MnSO_4$.

The average total length of top growth to a rooting exceeded that of the check in Champini by 74, 123, 124, and 64 per cent; in Pierce by 187, 161, 118, and 100 per cent; and in 41B by 356, 308, 317, and 206 per cent, respectively, for the treatments with $MnSO_4$, $K_3Fe(CN)_6$, $Na_2O_2$, and $KMnO_4$.

Similar increases were obtained in the number and average diameter of the roots. Although the check cuttings produced the smallest number of roots in all but two instances, these roots in no case had as great an average diameter as the roots of the treated lots.

The greater vigor and possibly the greater number of rootings produced are not the result only of a stimulated growth in the commencement of root formation, but also of a more rapid vegetative growth, which is apparent throughout the development in the nursery. This greater vigor of growth during early summer in the nursery is shown by figures 8 and 9. Figure 8 shows the relative development

of the cuttings shown in figure 6 five weeks after planting. The differences in top growth were equal to, if not greater than, the differences in callus formation as illustrated in the former figure. Figure 9 shows the top development of 41B cuttings eight weeks after plant-


Fig. 8. Showing the influence of treatment with $MnSO_4$ and $K_3Fe(CN)_6$ on the rate of growth of 41B cuttings in the nursery during early summer. Five weeks after planting. *a*, $MnSO_4$. *b*, Water. *c*, $K_3Fe(CN)_6$.


Fig. 9. The influence of treatment with $MnSO_4$ and $KMnO_4$ on the rate of growth of 41B cuttings in the nursery during early summer. Eight weeks after planting. *a*, $MnSO_4$. *b*, Water. *c*, $KMnO_4$.

ing. Here again the more rapid development, in the nursery, of the treated cuttings is pronounced.

The development of the cuttings of 41B shown in figures 6 and 8 at the end of the growing season is illustrated by the roots shown in figure 10. As this figure indicates, the more rapid development of the treated cuttings appears to continue throughout the growing season.

*An Apparent Difference in the Stimulating Action of Different Oxidizing Reagents.*—During some of the tests in continuous treatments, cuttings were immersed as much as four inches in the solutions of the reagents. It was observed that under these conditions the stimulation of root growth at the base of the cuttings by the reagents whose formulae show oxygen was greater than that by those whose formulae do not.

TABLE 11

THE STIMULATION OF ROOT GROWTH BY OXIDIZING REAGENTS IN THE PRESENCE OF AIR

| Reagent | Mol. conc. | Average number of roots per cutting | Average total length of roots per cutting, centimeters |
|---|---|---|---|
| $MnSO_4$ | .001 | 3.0 | 43 |
| $H_2O_2$ | .01 | 2.5 | 33 |
| $FeCl_3$ | .01 | 2.5 | 47 |
| $K_3Fe(CN)_6$ | .01 | 3.0 | 37 |

TABLE 12

THE EFFECT OF IMMERSION ON THE STIMULATION OF ROOT FORMATION BY OXIDIZING REAGENTS

| Reagent | Percentage of cuttings with roots at base | Percentage of cuttings with roots at surface of the liquid | Percentage of roots formed at base of the cutting |
|---|---|---|---|
| Check (water) | 10 | 100 | 5 |
| $MnSO_4$ .0001 per cent | 90 | 30 | 95 |
| $H_2O_2$ .0001 per cent | 80 | 0 | 100 |
| $K_3Fe(CN)_6$ .0015 per cent | 50 | 80 | 25 |
| $FeCl_3$ .001 per cent | 20 | 80 | 10 |

In the presence of air, the oxidation of the tissue of the cuttings appears to be independent of the presence or lack of oxygen in the formulae of the reagents. For instance, when cuttings were treated and then callused or rooted in sand, $K_3Fe(CN)_6$ and $FeCl_3$ stimulated root growth as much as $MnSO_4$ or $H_2O_2$. This is illustrated by the number and vigor of the roots produced as indicated in table 11.

On the other hand, when cuttings were rooted in the absence of air, as in water or in the solutions of a reagent, a considerable difference in the stimulation of the root growth became apparent between the reagents whose formulae show oxygen as compared to those whose formulae do not. This difference is indicated by the photo-

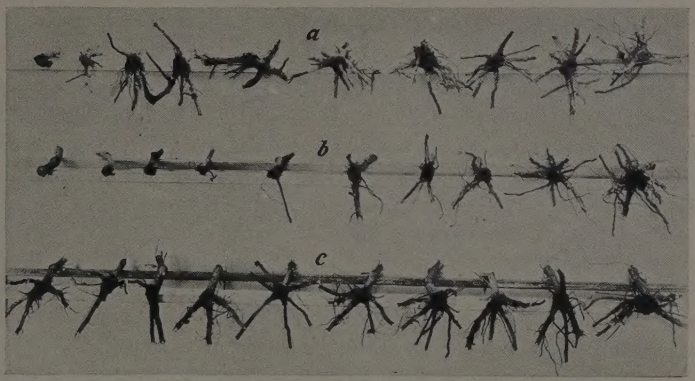


Fig. 10. The influence of treatment with $MnSO_4$ and $K_3Fe(CN)_6$ on the development of roots on 41B cuttings at the end of the growing season. *a*, $MnSO_4$. *b*, Water. *c*, $K_3Fe(CN)_6$.

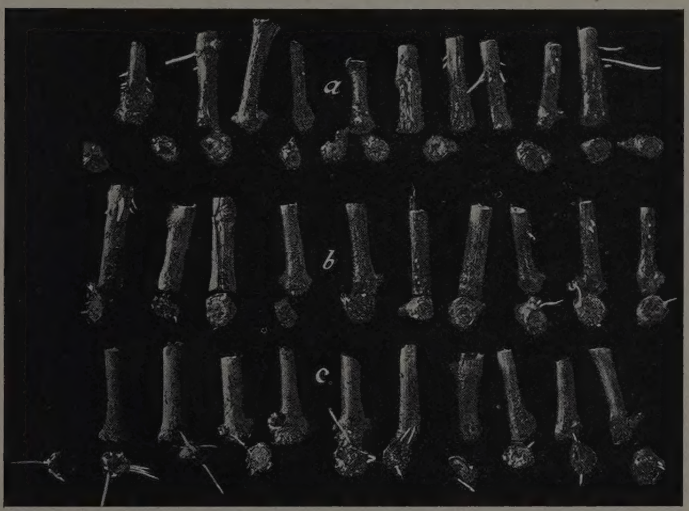


Fig. 11. The influence of the presence or lack of oxygen in the formulae of the reagents on the position of root formation on Pierce cuttings when rooted in the solutions of the reagents. Cuttings immersed one and one-half inches into the solutions. *a*, Water. *b*, $K_3Fe(CN)_6$. *c*, $MnSO_4$.

graphs of figure 11 and the data of table 12, which were obtained by immersing Pierce cuttings one and a half inches in water and solutions of the reagents, and by holding them at 30° C until roots developed. The solutions were changed every 48 hours.

The data of table 12 indicate that the stimulation of growth by the reagents not showing oxygen in their formulae is greatly retarded by the absence of air. In the case of the reagents carrying oxygen, however, there is a very decided stimulation in root growth even in the absence of air. As indicated by Rosa(3) there seems to be a specific effect of the oxygen, aside from the liberation of positive charges through the reduction of a salt or ion absorbed by the tissues of the cutting. That is, the reagents showing oxygen in their formulae seem to be capable of a certain amount of oxygenation of the tissues in addition to oxidation in the strict meaning of the term.

## SUMMARY

1. Selection by means of the iodine-starch test has resulted in a marked increase in the percentage of cuttings that root. The number of rootings of the cuttings showing a relatively high starch content was 264 per cent of that of the cuttings low in starch.

2. Chemical analyses indicate that the iodine-starch test gives a relatively accurate indication of the starch stored in the cuttings.

3. Early planting resulted in an increase in the number and vigor of vine rootings. The early planting appears to improve the development of the cuttings through its effect on the time of beginning of root formation.

4. The greatest stimulation of root development by the oxidizing reagents with a 24-hour treatment was obtained with the following range of concentrations: .001 to .0001 mol. $MnSO_4$, $Mn_2(SO_4)_3$, $K_3Fe(CN)_6$, and iodine; .01 to .001 mol. $MnO_2$, $FeCl_3$, and $Na_2O_2$, and .1 to .05 mol. $H_2O_2$ and $KMnO_4$.

5. The time required for treatment, within certain limits, is a function of the concentration of the solutions of the reagents.

6. Oxidizing reagents hastened both callus and root formation.

7. Oxidizing reagents improved the rooting of cuttings that root with difficulty.

8. The number of vigorous rootings of Champini was increased 186, 171, 186, and 117 per cent, respectively, by treatment with $MnSO_4$, $K_3Fe(CN)_6$, $Na_2O_2$, and $KMnO_4$. In 41B the increases were even greater.

9. Treatment with oxidizing reagents resulted in marked increases in the relative circumference of the cuttings and the average total length of top growth at the end of the first season in the nursery.

10. The development of the treated cuttings appears to be more vigorous than that of the untreated throughout the growing season in the nursery.

11. There appears to be a greater stimulation of root growth at the base of cuttings by the reagents whose formulae show oxygen than by those whose formulae do not, when the cuttings are rooted in the solutions of the reagents.

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